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Spinning and winding of polyester multifilament yarns using spinning additives and polyester multifilament yarns obtainable by the spinning process

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Spinning and winding of polyester multifilament yarns using spinning additives and polyester multifilament yarns obtainable by the spinning process

The present invention relates to processes for spinning and winding polyester filaments not less than 85% by weight, based on the total weight of the polyester filament, polybutylene terephthalate (PBT) and/or polytrimethylene terephthalate (PTMT), preferably PTMT, and also to the polyester multifilaments obtainable by the process. The present invention further relates to the use of the polyester multifilaments for draw texturing.

The production of continuous polyester multifilaments, especially of polyethylene terephthalate (PET) multifilaments, in a two-stage process is already known. In this process, the first stage comprises spinning and winding multifilaments which are fully drawn and heatset or draw-textured to bulky multifilament yarns in a second stage. The wound packages of the multifilament yarns can be stored for a prolonged period and transported at relatively high temperatures between the two stages without this having repercussions for the processing conditions of the second stage or for the quality of the products which are obtainable.

An overview of this field is given by the book *"Synthetische Fasern"* [Synthetic Fibers] by F. Fourné (1995), published by Hanser, Munich, by describing the fundamentals of the spinning and winding art.

Unlike PET multifilament yarns, however, polytrimethylene terephthalate (PTMT) or polybutylene terephthalate (PBT) multifilament yarns, not only directly after spinning and winding but also for several hours and days after winding, in the course of storage and transportation, especially at relatively

high ambient temperatures, exhibit a considerable tendency to shrink, which leads to yarn shortening. The package is compressed as a result, so that, in the extreme case, the package will shrink solid onto the winding mandrel and can no longer be removed. In the course of storage for a prolonged period or in the course of transportation, especially at elevated temperatures, the wound yarn package loses its desired "cheeselike" structure and will develop a so-called saddle with hard edges and a waisted center portion. As a result, textile data of the filaments deteriorate and problems develop when unwinding the packages. These problems, which do not arise with the processing of PET fibers, can generally only be avoided by limiting the yarn package weight to less than 2 kg.

It is further observed that, in contradistinction to PET multifilament yarns, PBT or PTMT multifilament yarns age rapidly in the course of storage. This is observed all the more at ambient temperatures in the range and above the polymer glass transition point. Structure hardening occurs and causes the characteristic properties of the multifilament yarns to change over time, for example decreased boiloff shrinkage. However, industrial practice demands storage-stable multifilament yarns having consistent yarn properties which are independent of the specific storage conditions and which permit continuous further processing and lead to multifilament yarns having uniform properties.

The differences between PET on the one hand and PBT and PTMT on the other are usually attributed to structural and property differences, as reported for example in Chemical Fibers Int., p. 53, vol. 50 (2000) and discussed at the 39th International Manmade Fibre Congress at Dornbirn from September 13 to 15, 2000. It is accordingly believed that different chain formations and also the higher glass transition point of PET

compared with PTMT/PBT are responsible for the property differences.

The first approaches to solving these problems are described in the patent applications WO 99/27168, WO 01/04393 and European patent EP 0,731,196 B1. WO 99/27168 discloses the production of polyester multifilament yarns not less than 90% by weight polytrimethylene terephthalate by spinning and drawing. The maximum spinning takeoff speeds reported are 2100 m/min, which are too low from an economic viewpoint, however. The polyester fibers obtainable by the process have a boiloff shrinkage between 5% and 16% and also a breaking extension of 20% to 60%, so that they are only of limited usefulness for further processing, since the low breaking extension suggests an elevated number of processing faults in the course of further processing. Furthermore, the resulting yarn will have a reduced breaking strength.

WO 01/04393 relates to a method for producing PTMT multifilaments wherein the multifilament yarns are heat treated using heated godets. However, neither the storage nor the transportation stability, especially at relatively high temperatures, is described. A disadvantage of the method are the required low spinning takeoff speeds. An economically desirable speed increase necessitates a shorter contact time of the multifilaments on the heated godet, which leads to a deterioration in the long-term storage stability of the resulting yarn packages and also of the POY boiloff shrinkage at relatively high temperatures.

The European patent EP 0,731,196 B1 claims a process for spinning, drawing and winding a synthetic yarn by subjecting the yarn to a heat treatment after drawing and before winding to reduce its tendency to shrink. Synthetic fibers which can be used include polytrimethylene terephthalate fibers. In

EP 0,731,196 B1, the heat treatment is effected by the synthetic yarn being guided in close vicinity to but essentially contactlessly along an elongate heating surface. A treatment of the yarn package is not described in the reference. Nor does the reference reveal any information with regard to the storage stability and the transportation stability of the wound yarn packages.

A further problem which is customarily to be observed during the spinning and winding of multifilament yarns, especially at high speeds, is the noise nuisance, especially in the vicinity of the winder. It has therefore been proposed that the winder unit be encased in an acoustically insulating housing. However, a heat treatment of the wound yarn package within this acoustically insulating housing has hitherto not been described in the prior art.

It is, then, an object of the present invention to solve the aforementioned problems. It is a particular object of the present invention to provide a process for spinning and winding polyester multifilament yarns not less than 85% by weight, based on the total weight of the filaments, PBT and/or PTMT whereby polyester multifilament yarns are simple to produce and wind up. The polyester multifilaments shall advantageously have breaking extension values of > 60% and preferably in the range 75%-145%, a boiloff shrinkage of 0 to 10% and a high uniformity with regard to filament parameters.

It is a further object of the present invention to provide an economical industrial process for spinning and winding polyester multifilament yarns. The process of the invention shall permit very high spinning takeoff speeds, preferably above 2200 m/min, and high yarn weights on the package of more than 2 kg and especially of more than 4 kg, the wound yarn packages

advantageously having a uniform cheese shape without bulging and sloughed coils.

It is yet a further object of the present invention to improve the storability of the polyester multifilaments obtainable by the process of the invention. They shall be storable for a prolonged period, for example 4 weeks. Ideally, the package shall not compact in the course of storage, especially shall not shrink solid on the winding mandrel and form a saddle having hard edges and a waisted center portion, so that there shall be no problems unwinding from the package.

According to the invention, the polyester multifilaments shall be simple to further process in a drawing or draw-texturing operation, especially at high texturing speeds, preferably above 450 m/min. The multifilament yarns obtainable by draw texturing shall have excellent material properties, for example a high breaking strength and a high breaking extension, a low number of broken filaments and a uniform dyeability.

These and other objects not expressly mentioned but readily derivable or apparent from the related matters discussed herein at the beginning are achieved by a process for spinning and winding that comprises all the features of claim 1. Advantageous modifications of the process according to the invention are protected in subclaims appendant to claim 1. The polyester multifilament yarn obtainable by the spinning process is described in an independent product claim. The draw texturing of the partially oriented polyester filament is claimed in process claim 21, whereas product claims 22 and 23 are to the bulky filaments obtainable by the draw texturing.

The present invention accordingly provides a process for producing and winding polyester multifilament yarns not less than 85% by weight based on the total weight

of the multifilament yarn polybutylene terephthalate (PBT) and/or polytrimethylene terephthalate (PTMT) that contain between 0.05% by weight and 2.5% by weight based on the total weight of the multifilament yarn of at least one additive polymer extensibility enhancer, by a wound yarn package which is stable in long-term storage and insensitive to elevated temperatures during storage and transportation being provided by heat-treating the wound polyester multifilament yarn package at a temperature in the range from > 45°C to 65°C.

This unforeseeable process provides polyester multifilaments which maintain their excellent material properties even after 4 weeks of storage, especially after storage or transportation at relatively high temperatures up to 65°C. No significant worsening in the uniformity values of the yarn due to aging and no shrinkage of the spun fiber on the bobbin are observed.

At the same time, the process of the invention has a number of further advantages. These include:

⇒ The process of the invention is simple and economical to practice on a large industrial scale. More particularly, the process permits spinning and winding at high takeoff speeds of at least 2200 m/min and the production of packages holding high yarn weights of more 2 kg and especially of more than 4 kg, the wound yarn packages having a uniform cheese shape without bulges and sloughed coils.

⇒ The use of spinning additives makes it possible to achieve takeoff speeds of up to 6000 m/min. The equipment can be operated particularly economically as a result.

⇒ The polyester multifilament yarns obtainable by the process can thus be further processed in a

drawing or draw-texturing operation simply, economically and on a large industrial scale. In the operation, the texturing can be carried out at speeds above 450 m/min.

⇒ Owing to the high uniformity of the polyester multifilaments yarns obtainable by the process, it is simple to achieve good package build to ensure uniform and substantially defect-free dyeing and further processing of the polyester multifilament yarns.

⇒ The packages obtained on winding are shape stable, readily removable from the winding mandrel and retain their shape even after prolonged storage of for example 4 weeks or transportation at temperatures up to 65°C, especially at temperatures between the glass transition point of the polymer and 65°C.

⇒ Higher breaking extensions are obtained at higher spinning speeds than without additive, so that a higher draw ratio results in the further processing, with a beneficial effect on the economics of the process.

⇒ The POY boiloff shrinkage obtained of 0-10% ensures a high stability for the yarn parameters on storage. Even relatively high transportation temperatures up to 65°C will cause the boiloff shrinkage to decrease by no more than 10% absolute. There is no deformation of the wound package.

⇒ The yarns obtainable by draw texturing the multifilament yarns have a high breaking extension and also a high breaking strength.

The invention will now be described in more detail with occasional reference to the accompanying drawings, in which

Fig. 1 is a schematic representation of an apparatus for taking or winding up one or more multifilament yarns,

Fig. 2 is a schematic representation of a cheeselike yarn package,

Fig. 3 is a schematic representation of a deformed yarn package featuring a saddle with hard edges and a waisted center portion.

The present invention provides a process for producing and for winding polyester multifilament yarns not less than 85% by weight polybutylene terephthalate (PBT) and/or polytrimethylene terephthalate (PTMT), based on the total weight of the filament. Polybutylene terephthalate (PBT) and/or polytrimethylene terephthalate (PTMT) are known to one skilled in the art. Polybutylene terephthalate (PBT) is obtainable by polycondensation of terephthalic acid with equimolar amounts of 1,4-butanediol and polytrimethylene terephthalate is obtainable by polycondensation of terephthalic acid with equimolar amounts of 1,3-propanediol. Mixtures of the two polyesters are also conceivable. According to the invention, PTMT is preferred.

The polyesters may be homopolymers or copolymers. Useful copolymers include especially copolymers which, as well as PTMT and/or PBT repeat units, contain up to 15 mol%, based on all the repeat units of the polyesters, of repeat units of customary comonomers, for example ethylene glycol, diethylene glycol, triethylene glycol, 1,4-cyclohexanedimethanol, polyethylene glycol, isophthalic acid and/or adipic

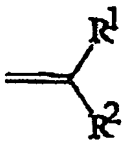
acid. For the purposes of the present invention, however, polyester homopolymers are preferred.

The polyesters of the invention may include customary amounts of further additives as admixtures, such as catalysts, stabilizers, antistats, antioxidants, flame retardants, dyes, dye uptake modifiers, light stabilizers, organic phosphites, optical brighteners and delusterants. Preferably, the polyesters include 0 to 5% by weight of additives, based on the total weight of the filament.

The polyesters may further include a small fraction, preferably up to 0.5% by weight, based on the total weight of the filament, of brancher components. Preferred brancher components according to the invention include polyfunctional acids, such as trimellitic acid, or pyromellitic acid, or tri- to hexavalent alcohols, such as trimethylolpropane, pentaerythritol, dipentaerythritol, glycerol or corresponding hydroxy acids.

In the context of the present invention, the PBT and/or PTMT are admixed with 0.05% by weight to 2.5% by weight, based on the total weight of the filament, of additive polymers as extensibility enhancers. Particularly useful additive polymers for the purposes of the invention include the hereinbelow specified polymers and/or copolymers:

1. A polymer obtainable by polymerization of monomers of the general formula (I):



(I)

where R^1 and R^2 are substituents consisting of the optional atoms C, H, O, S, P and halogen atoms and the sum total of the molecular weights of R^1 and R^2 is at least 40. Exemplary monomer units include acrylic acid, methacrylic acid and CH_2=CR-COOR', where R is an H atom or a CH_3 group and R' is a C_{1-15}-alkyl radical or a C_{5-12}-cycloalkyl radical or a C_{6-14}-aryl radical, and also styrene and C_{1-3}-alkyl-substituted styrenes.

2. A copolymer containing the following monomer units:

A = acrylic acid, methacrylic acid or CH_2=CR-COOR', where R is an H atom or a CH_3 group and R' is a C_{1-15}-alkyl radical or a C_{5-12}-cycloalkyl radical or a C_{6-14}-aryl radical,

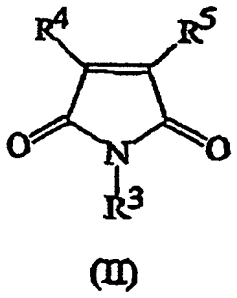
B = styrene or C_{1-3}-alkyl-substituted styrenes,

the copolymer consisting of 60 to 98% by weight of A and 2 to 40% by weight of B, preferably of 83 to 98% by weight of A and 2 to 17% by weight of B and more preferably of 90 to 98% by weight of A and 2 to 10% by weight of B (sum total = 100% by weight).

3. A copolymer containing the following monomer units:

C = styrene or C_{1-3}-alkyl-substituted styrenes,

D = one or more monomers of the formula II, III or IV



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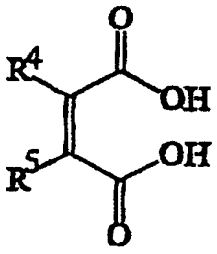

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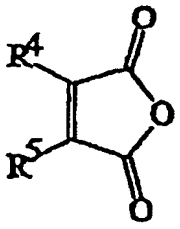


(IV)

where R^3, R^4 and R^5 are each an H atom or a C_{1-15}-alkyl radical or a C_{6-14}-aryl radical or a C_{5-12}-cycloalkyl radical,

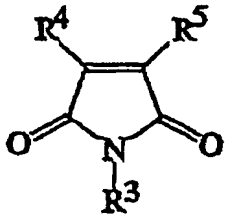
the copolymer consisting of 15 to 95% by weight of C and 2 to 80% by weight of D, preferably of 50 to 90% by weight of C and 10 to 50% by weight of D and more preferably of 70 to 85% by weight of C and 15 to 30% by weight of D, the sum total of C and D being 100% by weight.

4. A copolymer containing the following monomer units:

E = acrylic acid, methacrylic acid or CH_2=CR-COOR' where R is an H atom or a CH_3 group and R' is a C_{1-15}-alkyl radical or a C_{5-12}-cycloalkyl radical or a C_{6-14}-aryl radical,

F = styrene or C_{1-3}-alkyl-substituted styrenes,

G = one or more monomers of the formula II, III or IV



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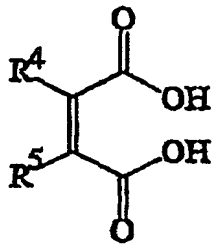

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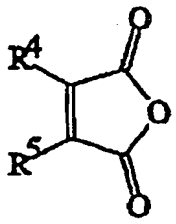

(IV)

where R^3, R^4 and R^5 are each an H atom or a C_{1-15}-alkyl radical or a C_{5-12}-cycloalkyl radical or a C_{6-14}-aryl radical,

H = one or more ethylenically unsaturated monomers which are copolymerizable with E and/or with F and/or G and are selected from the group consisting of α-methylstyrene, vinyl acetate, acrylic esters, methacrylic esters other than E, acrylonitrile, acrylamide, methacrylamide, vinyl chloride, vinylidene chloride, halogen-substituted styrenes, vinyl ethers, isopropenyl ethers and dienes,

the copolymer consisting of 30 to 99% by weight of E, 0 to 50% by weight of F, >0 to 50% by weight of G and 0 to 50% by weight of H, preferably of 45 to 97% by weight of E, 0 to 30% by weight of F, 3 to 40% by weight of G and 0 to 30% by weight of H and more preferably of 60 to 94% by weight of E, 0 to 20% by weight of F, 6 to 30% by weight of G and 0 to 20% by weight of H, the sum total of E, F, G and H being 100% by weight.

Component H is an optional component. Although the advantages to be achieved according to the present invention are already obtainable by means of copolymers which contain components from groups E to G, the advantages to be achieved according to the present invention are also obtained when further monomers from

group H are involved in the construction of the copolymer to be employed according to the present invention.

Component H is preferably chosen such that it has no adverse effect on the properties of the copolymer to be used according to the present invention.

Component H can be employed, inter alia, to modify the properties of the copolymer in a desired manner, for example through increases or improvements in the flow properties on heating to the melting temperature, or to reduce any residual color in the copolymer or by using a polyfunctional monomer in order thereby to introduce a certain degree of crosslinking into the copolymer.

As well as for these reasons, H can also be chosen such that any copolymerization of components E to G is augmented or made possible in the first place, as in the case of MA and MMA, which do not copolymerize on their own, yet will copolymerize readily on addition of a third component such as styrene.

Useful monomers for this purpose include vinyl esters, esters of acrylic acid, for example methyl acrylate and ethyl acrylate, esters of methacrylic acid other than methyl methacrylate, for example butyl methacrylate and ethylhexyl methacrylate, acrylonitrile, acrylamide, methacrylamide, vinyl chloride, vinylidene chloride, styrene, α-methylstyrene and the various halogen-substituted styrenes, vinyl ethers, isopropenyl ethers, dienes, for example 1,3-butadiene, and divinylbenzene. The reduction in copolymer color may be particularly preferably achievable through use of an electron-rich monomer, for example through the use of a vinyl ether, vinyl acetate, styrene or α-methylstyrene.

Particular preference among the compounds of component H is given to aromatic vinyl monomers, for example styrene or α-methylstyrene.

The production of the aforementioned polymers and/or copolymers is very well known to one skilled in the art. Details are discernible for example from the document WO 99/07927, the disclosure of which is hereby fully incorporated herein by reference.

Particular preference for the purposes of the present invention is given to additive polymers and/or copolymers in the form of bead polymers whose particle size lies in a particularly favorable range. The additive polymers and/or copolymers to be used according to the present invention, for example by being mixed into the melt of the fiber polymers, are advantageously in the form of particles having an average diameter in the range from 0.1 to 1.0 mm. However, larger or smaller beads or pellets can also be employed. The additive polymers and/or copolymers may also already be contained in chips of the matrix polymer, so that there is no need for metered addition.

Preference is further given to additive polymers and/or copolymers which are amorphous and insoluble in the polyester matrix. They preferably possess a glass transition temperature of 90 to 200°C, the glass transition temperature being determined in a known manner, preferably by differential scanning calorimetry. Further details are discernible from the prior art, for example from WO 99/07927, the disclosure of which is hereby expressly incorporated herein by reference.

Preferably, the additive polymer and/or copolymer is selected so that the ratio of the melt viscosities of the additive polymer and/or copolymer and of the matrix polymer is in the range from 0.8:1 to 10:1 and

preferably in the range from 1.5:1 to 8:1. The melt viscosity is measured in a known manner using an oscillation rheometer at an oscillation frequency of 2.4 Hz and a temperature equal to the melting temperature of the matrix polymer plus 28°C. For PTMT, the temperature at which the melt viscosity is measured is 255°C. Further details may again be found in WO 99/07927. The melt viscosity of the additive polymer and/or copolymer is preferably higher than that of the matrix polymer, and it has been determined that the choice of a specific viscosity range for the additive polymer and/or copolymer and the choice of the viscosity ratio contribute to optimizing the properties of the yarn product. Given an optimized viscosity ratio, it is possible to minimize the amount of additive polymer and/or copolymer added and so, inter alia, improve the economics of the process. The polymer blend to be spun preferably contains 0.05 to 2.5% by weight and more preferably 0.25 to 2.0% by weight of additive polymer and/or copolymer.

The choice of the favorable viscosity ratio provides a narrow distribution of the particle sizes of the additive polymer and/or copolymer in the polymer matrix combined with the desired fibril structure for the additive polymer and/or copolymer in the fiber. The high glass transition temperature of the additive polymer and/or copolymer compared with the matrix polymer ensures rapid consolidation of this fibril structure in the spun fiber. The maximum particle sizes of the additive polymer and/or copolymer amount to about 1 000 nm immediately following emergence from the spinneret, while the average particle size is 400 nm or less. The favorable fibril structure is obtained after the fiber has been drawn down, the filaments containing at least 60% by weight of the additive polymer and/or copolymer in the form of fibrils having lengths in the range from 0.5 to 20 µm and diameters in the range from 0.01 to 0.5 µm.

Useful polyesters for the invention are preferably thermoplastically formable and can be spun into filaments and wound up. In this context, particularly advantageous polyesters have a limiting viscosity number in the range from 0.70 dl/g to 0.95 dl/g.

A polymer melt can be taken for example directly from the final reactor of a polycondensation plant or be produced from solid polymer chips in a melting extruder.

One known way of incorporating the spinning additive is to meter it in molten or solid form into the matrix polymer and disperse it therein homogeneously to form fine particles. Advantageously, an apparatus as described in DE 100 22 889 can be used.

The process of the present invention is not limited to specific spinning processes; on the contrary, all conventional spinning processes known from the prior art can be used. Therefore, although a very particularly preferred spinning operation will now be described, reference is made to the general technical knowledge, especially to the disclosure content of the book *Synthetische Fasern* [Synthetic Fibers] from F. Fourné (1995), published by Hanser, Munich.

In a particularly preferred embodiment of the process of the invention, the melt or melt mixture of the polyester is pumped by spinning pumps at constant speed, the speed being calculated by a known formula so that the desired fiber linear density is obtained, into spinneret packs to be extruded through the holes in the die plate of the pack to form molten filaments.

The melt may be prepared for example from polymer chips in an extruder, in which case it is particularly favorable for the chips first to be dried to a water

content ≤30 ppm and especially to a water content ≤15 ppm.

The temperature of the melt, which is commonly referred to as the spinning temperature and which is measured above the spinning pump, depends on the melting point of the polymer or polymer blend used. It is preferably situated in the range given by formula 1:

Formula 1:

$T_m + 15°C \leq T_{Sp} \leq T_m + 45°C$

where

T_m is the melting point of the polyester [°C]

T_{Sp} is the spinning temperature [°C].

The specified parameters serve to limit the hydrolytic and/or thermal viscosity degradation, which should advantageously be very low. In the context of the present invention, a viscosity degradation of less than 0.12 dl/g and especially less than 0.08 dl/g is desirable.

Melt homogeneity has a direct influence on the material properties of the spun filaments. As well as static mixers in the product line, it is therefore preferable to use a further static mixer having at least one element and installed below the spinning pump to homogenize the melt.

Die plate temperature, which depends on the spinning temperature, is controlled by the plate's secondary heating system. Useful secondary heating systems include for example a spinning beam heated with "Diphyl" or additional convective or radiative heaters. The temperature of the die plates is customarily equal to the spinning temperature.

A temperature increase at the die plate can be obtained through the pressure gradient in the spinneret pack.

Known derivations, for example K. Riggert "Fortschritte in der Herstellung von Polyester-Reifenkordgarn" Chemiefasern **21**, page 379 (1971), describe a temperature increase of about 4°C per 100 bar of pressure drop.

It is further possible to control die pressure through the use of loose filter media, especially through the use of steel sand having an average particle size between 0.10 mm and 1.2 mm, preferably between 0.12 mm and 0.75 mm and/or filter disks, which can be formed from woven or nonwoven metal fabrics having a fineness ≤40 µm.

In addition, the pressure drop in the die hole contributes to the overall pressure. The die pressure is preferably set between 80 bar and 450 bar, especially between 100 bar and 250 bar.

The spinline extension ratio i_{Sp}, i.e. the ratio of the takeoff speed to the extrusion speed, is calculated in accordance with US 5,250,245 via formula 2 from the density of the polymer or polymer mixture, the spinneret hole diameter and the filament linear density:

Formula 2:

$$i_{Sp} = 2.25 \bullet 10^5 \bullet (\delta \bullet \pi) \bullet D^2\,(cm)/dpf\,(den)$$

where

δ = density of melt [g/cm^3]; for PTMT = 1.12 g/cm^3

D = spinneret hole diameter [cm]

dpf = denier per filament [den].

For the purposes of the present invention, the spinline extension ratio is advantageously between 70 and 500, especially between 100 and 250.

The length/diameter ratio of the spinneret hole is preferably selected to be between 1.5 and 6, especially between 1.5 and 4.

The extruded filaments pass through a quench delay zone. The quench delay zone is configured directly below the spin pack as a recess zone in which the filaments emerging from the spinneret holes are protected from the direct action of the cooling gas and are delayed in spinline extension or cooling. An active part of the recess is constructed as an extension of the spin pack into the spinning beam, so that the filaments are surrounded by heated walls. A passive part is formed by insulating layers and unheated frames. The lengths of the active recess are advantageously between 0 to 100 mm and those of the passive part advantageously between 20 to 120 mm, preferably subject to an overall length of 30 - 200 mm, preferably 30 - 120 mm.

As an alternative to the active recess, a reheater can be disposed below the spinning beam. In contrast to the active recess, this zone of cylindrical or rectangular cross section then comprises at least one heating system independent of the spinning beam.

In the case of radial porous quenching systems which surround the spinline concentrically, the quench delay can be attained using cylindrical shrouds.

The filaments are subsequently cooled to temperatures below the solidification temperature. For the purposes of the invention, the solidification temperature is the temperature at which the melt passes into the solid state.

In the context of the present invention, it has been determined to be particularly advantageous to cool the filaments down to a temperature at which they are

essentially no longer tacky. It is particularly advantageous to cool the filaments to temperatures below their crystallization temperature, especially to temperatures below their glass transition temperature.

Means for quenching or cooling filaments are known from the prior art. It is particularly useful according to the invention to use cooling gases, especially cooled air. The temperature of the cooling air is preferably in the range from 12°C to 35°C, and especially in the range from 16°C to 26°C. The velocity of the cooling air is advantageously in the range from 0.20 m/sec to 0.55 m/sec.

The filaments may be cooled using for example single end systems comprising single cooling tubes having a perforated wall. Cooling of each individual filament is obtained through active cooling air supply or by utilizing the self-suction effect of the filaments. As an alternative to the individual tubes, it is also possible to use the familiar crossflow quench systems.

In a particular embodiment of the cooling and spinline extension region, the filaments emerging from the delay zone are exposed to cooling air in a zone 10 to 175 cm and preferably 10 - 80 cm in length. A zone 10 - 40 cm in length is particularly suitable for filaments having a linear density at windup ≤1.5 dtex per filament and a zone length of 20 - 80 cm is particularly suitable for filaments having a linear density between 1.5 and 9.0 dtex per filament. The filaments and the accompanying air are subsequently conjointly passed through a channel having a reduced cross section at a ratio of the air velocity to the spinline speed at takeoff in the range from 0.2 to 20:1, preferably in the range from 0.4 to 5:1, by controlling the cross-sectional constriction and the dimensioning in the spinline transportation direction.

After the filaments have been cooled down to temperatures below the solidification point, they are converged to form a yarn bundle. A suitable distance according to the invention for the point of convergence from the underface of the spinneret can be determined using conventional methods for online measurement of the yarn speed and/or yarn temperature, for example using a laser doppler anemometer from TSI/Germany or an infrared camera from Goratec/Germany type IRRIS 160. It is advantageously in the range from 500 to 2 500 mm, preferably from 500 to 1 800 mm. Filaments having an as-spun linear density ≤3.5 dtex are preferably converged into a multifilament bundle at a smaller distance ≤1 500 mm, while thicker filaments are preferably converged at a greater distance.

It is advantageous for the purposes of the present invention that preferably all surfaces which come into contact with the spun filament are fabricated of particularly low-friction materials. This substantially avoids broken filaments and provides higher quality filament yarns. Particularly suitable for this purpose are low-friction surfaces of the "TriboFil" specification from Ceramtec/Germany.

The filaments are converged in an oiler pin which supplies the yarn with the desired amount of spin finish at a uniform rate. A particularly suitable oiler pin is characterized by an inlet part, the yarn duct with oil inlet orifice and an outlet part. The inlet part is funnellike, so that contact by the dry filaments is avoided. The contact point of the filaments occurs within the yarn duct after the supply of spin finish. Yarn duct and oil inlet orifice are conformed in width to the yarn linear density and the number of filaments. Orifices and widths in the range from 1.0 mm to 4.0 mm are particularly suitable. The outlet part of the oiler pin is configured as a uniformizing zone, which preferably comprises oil

reservoirs. Such oilers are obtainable for example from Ceramtec/Germany or Goulston/USA.

The uniformity of oil application is of immense importance for the invention. The uniformity can be determined for example using a Rossa meter as per the method described in Chemiefasern/Textilindustrie, 42/94 November 1992 at page 896. Preferably, such a procedure provides standard deviation values for the oil application which are less than 90 digits and especially less than 60 digits. Particular preference for the purposes of the invention is given to oil application standard deviation values of less than 45 digits and especially less than 30 digits. A standard deviation value of 90 or 45 digits corresponds approximately to 6.2% or 3.1% of the coefficient of variation, respectively.

It is particularly advantageous for the purposes of the present invention to design spin finish lines and pumps to be self-degassing to avoid gas bubbles, since gas bubbles can lead to an appreciable variation in oil application.

According to the invention, it is particularly preferable for the filaments to be entangled before the yarn is wound up. In the context of the present invention, jets having closed yarn ducts will be found to be particularly suitable, since such systems prevent snubbing of the yarn in the feed slot even at low yarn tension and high air pressure. The entangling jets are preferably disposed between godets and the yarn exit tension is controlled via the different speeds of the inlet and outlet godets. The yarn exit tension should not exceed 0.20 cN/dtex and should primarily have values between 0.05 cN/dtex and 0.15 cN/dtex. The entangling air pressure is between 0.5 and 5.5 bar, or at most 3.0 bar in the case of takeup speeds of up to 3 500 m/min.

The yarns are preferably entangled to node counts of at least 10 n/m. Maximum nodeless gaps of less than 100 cm and node count coefficient variation values below 100% are of particular interest. Advantageously, the employment of air pressures above 1.0 bar provides node counts ≥15 n/m, which are characterized by high uniformity in that the coefficient of variation is not more than 70% and the maximum nodeless gap is 50 cm. In actual service, systems of the LD type from Temco/Germany, the double system from Slack & Parr/USA or Polyjet from Heberlein have been found to be particularly useful.

The circumferential speed of the first godet unit is referred to as takeoff speed. Further godet systems can be employed before the yarn is wound up in the wind assembly to form packages (bobbins) on tubes for the multifilament yarn to be drawn, heatset and/or relaxed.

In the context of a particularly preferred embodiment of the present invention, the multifilament yarns are heat treated, preferably at a temperature in the range from 50 to 150°C, before being wound up, the heat treatment being actualizable by any known process. It has been determined to be most favorable for the polyester multifilament yarns to be heat treated by using heated godets. Godets useful for this purpose include those described in general terms in the book *Synthetische Fasern* [Synthetic Fibers] by F. Fourné (1995), published by Hanser, Munich.

In a further preferred embodiment of the present invention, the polyester multifilament yarns are heat treated using heated gases, especially by using heated air.

In a third preferred embodiment of the present invention, the multifilament yarns are heat treated using radiant heat.

The heat treatment of the multifilament yarns can also be achieved by leading the yarn in close vicinity to but essentially contactlessly along an elongate heating surface, in which case a suitable embodiment of this process is described in the document EP 731,196, for example.

Stable, defect-free packages are a basic prerequisite for defect-free winding of the yarn and for an ideally defect-free further processing. Therefore, in the context of the present invention, it has been found to be most favorable to employ a takeup tension in the range of 0.025 cN/dtex - 0.15 cN/dtex and preferably in the range of 0.03 cN/dtex - 0.08 cN/dtex.

A further important parameter of the process according to the invention is the yarn tension setting above and between the takeoff godets. As will be known, this tension is made up essentially of Hamana's actual orientation tension, the frictional tension on the yarn guides and the oiler and the yarn-air frictional tension. For the purposes of the present invention, the yarn tension above and between the takeoff godets is in the range from 0.05 cN/dtex to 0.20 cN/dtex and preferably in the range between 0.08 cN/dtex and 0.15 cN/dtex.

An excessively low tension below 0.05 cN/dtex no longer provides the desired degree of partial orientation. When the tension exceeds 0.20 cN/dtex, this tension will frequently induce a memory effect in the course of winding and storing the bobbins that leads to a deterioration in yarn parameters.

The tension is controlled according to the invention by the distance of the oiler from the jet spinneret, the frictional surfaces and the length of the gap between oiler and takeoff godet. This length is advantageously not more than 6.0 m and preferably less than 2.0 m, the spinning system and the takeoff machine being disposed in such a way by parallel construction as to ensure a straight yarn path.

The geometric parameters also describe the conditioning time of the yarn between converging point and takeup. The fast relaxation during the period has an effect on the quality of package build. The conditioning time so defined is preferably chosen to be between 50 and 200 ms.

The takeup speed of the POY is preferably between 2 200 m/min and 6 000 m/min according to the invention. It is advantageous to choose a speed between 2 500 m/min and 6 000 m/min. It is particularly preferable for the polymer blends to be wound up at speeds in the range from 3500 m/min to 6000 m/min.

In the context of the present invention, the wound polyester multifilament yarn package is heat treated at a temperature in the range from > 45°C to 65°C. The duration of the heat treatment is freely choosable; however, it is naturally distinctly longer than in the case of known filament treatment methods involving, for example, godets or hotrails. It has been determined to be most favorable according to the invention for these wound yarn packages to be heat treated in the aforementioned temperature range for at least 5 minutes, preferably at least 10 minutes, more preferably at least 20 minutes and especially at least 30 minutes, the times mentioned starting with the start of the winding or takeup operation.

The heat treatment can be carried out in any known manner. Suitable processes include processes in which the principle of the heat treatment rests on thermal conduction, thermal convection and/or thermal radiation. In a preferred embodiment of the present invention, the wound yarn package is heat treated using heated rolls or rollers, preferably by using at least one contact roller which at the same time measures and controls the windup speed. In a further preferred embodiment of the present invention, the wound yarn package is heat treated using radiant heat.

In a third preferred embodiment of the present invention, the wound yarn package is heat treated using heated gases. Suitable gases include air and inert gases, for example nitrogen, helium and/or argon. The use of heated air has been determined to be most favorable in this context. The temperature of the heated gases is preferably conformed such that it is ensured that the temperature within the housing is in the range from >45°C to 65°C. The temperature of the heated gases is therefore preferably in the range from >45°C to 65°C. The relative humidity of the gases is preferably in the range from 40 to 90%. The flow rate of the gases at the gas inlet is preferably in the range from 5 to 100 m^3/h.

The heat treatment of the wound yarn packages is preferably carried out using an apparatus for winding up one or more multifilament yarns which comprises a housing and a rotatable spindle on which tubes can be secured such that the tubes are encased within the housing. The heat treatment preferably takes within the housing, preferably by heating the wound yarn package by thermal conduction, thermal convection and/or thermal radiation.

In this connection, the rotatable spindle is part of a winder. The at least one tube is clamped onto the chuck

of the rotatable spindle and the at least one multifilament yarn is wound onto the at least one tube to form at least one wound yarn package. After winding, the at least one tube which carries the wound yarn package can be removed from the chuck.

Any type of winder known from the prior art can be used in the present invention, as long as the objectives of the invention are achieved. For further details, reference is therefore made to the technical literature, especially to the book Synthetische Fasern [Synthetic Fibers] by F. Fourné (1995), published by Hanser, Munich. As with the conventional, prior art winders, the present invention permits the winding at one and the same time of one or more, especially 1 to 12, multifilament yarns on one spindle. The simultaneous winding of very many multifilament yarns is particulary preferred according to the invention to improve the efficiency of the spinning operation.

The housing of the apparatus for winding one or more multifilament yarns can be made from any known material. However, it has been determined to be particularly advantageous for the housing to be made from a thermally insulating material which is preferably also acoustically insulating. Suitable materials include plastics, especially plastics having a glass transition temperature >65°C, metals, such as for example stainless steel and metal alloys. The thermally insulating material can have a single-layered structure or a multi-layered structure having two, three or more layers. Preferably, the thermal insulating material has a thermal conductivity coefficient < 10 W/(m*K), more preferably < than 1 W/(m*K), even more preferably > 0.5 W/(m*K) and most preferably > 0.1 W/(m*K). Particularly advantageous results are obtained when the thermally and preferably acoustically insulating material is three layered with the layer in the middle consisting of insulating

material having a thermal conductivity coefficient < 0.1 W/(m*K) and the outer layers preferably comprise a metal or metal alloy and advantageously consist of a metal or metal alloy.

The size of the housing is preferably such that it accommodates the winder either completely or at least the chuck with the maximum diameter of the tube including the wound yarn package. It has also been determined to be advantageous for any additional winding equipment, preferably comprising a contact roller for controlling the winding speed and preferably a traversing device, likewise to be accommodated in the housing. This minimum size for the housing permits a defect-free winding operation of a high-quality yarn.

Alternatively, it is likewise advantageous to minimize the size of the housing in order that standard working conditions outside the housing in the winding room may be made possible and the costs created by the heating of the interior of the housing may be minimized. The housing should preferably make it possible to introduce multifilament yarns in a simple manner, the easy removal of the wound yarn packages and also the production of wound yarn packages having high weight, preferably of more than 2 kg and more preferably of more than 4 kg.

In a particularly preferred embodiment of the present invention, the heat treatment of the wound yarn package is effected by means of at least one heated gas within the housing, the gas or gases preferably being introduced into the housing through an inlet and preferably being removed from the housing through an outlet. It has in this connection been determined to be particularly advantageous for the inlet and outlet to be connected to each other such that the gas can circulate in a circulation system which comprises inlet and the outlet. The gas, viewed in the direction of

movement of the yarn, is advantageously fed behind the tube and removed before the tube. Although the gas can also be heated within the housing, it is preferably heated outside the housing to ensure a constant and uniform temperature distribution within the housing.

In the context of this embodiment, it is particularly advantageous for the temperature within the housing to be measured by means of at least one temperature sensor and the temperature of the gas to be conformed thereto by suitable heating, preferably outside the housing, such that the temperature within the housing falls in the range from >45°C to 65°C. Here, the temperature sensor and the heating element for heating the gas are preferably connected to each other such that the temperature of the gas can be controlled within a predetermined range, preferably in the range from >45°C to 65°C.

Advantageously, the temperature is measured within the housing, compared with the predetermined value and, depending on the temperature difference, the temperature of the heated gas is suitably conformed (increased, lowered or maintained), so that the temperature within the housing falls in the desired range.

It is further advantageous for the temperature within the housing to be measured at at least two points, viewed in the direction of movement of the yarn, preferably before and behind the sleeve, in order to check and ensure that the temperature within the housing is constant. The occurrence of a temperature gradient should be avoided by suitable conformation of the gas temperature and or its flow rate.

To introduce the multifilament yarns before the start of winding, the housing preferably has an opening, and an opening in the shape of a slot is particularly

preferred. The slot is preferably disposed such that the multifilament yarns, viewed in the direction of movement of the yarns, can be introduced transversely. Advantageously, the slot is partly covered by suitable means during the winding in order that the interior of the housing be insulated from its environment, so that a possible temperature gradient within the housing is ideally avoided. In a particularly preferred embodiment of the present invention, the cover takes the form of a flap which is secured to the outer surface of the housing, which can partly cover the slot during the spinning and winding operation and which can be opened to introduce the multifilament yarns. The flap preferably has one or more apertures through which the multifilament yarns can pass into the housing when the flap is closed. The position and size of the one or more openings is suitably chosen according to the traverse length of the wound yarn package.

The winding apparatus which can be used in this embodiment preferably comprises a traversing device for controlling the specific shape of the wound yarn package. The present invention is not restricted to the use of specific traversing devices; on the contrary, any known traversing device can be used as long as the objectives of the present invention are achieved.

In the context of this embodiment of the present invention, the position of the traversing device is not subject to any restrictions; for example, it can be disposed outside the housing, preferably directly above the opening for introducing the multifilament yarn into the housing, in which case the opening preferably has the shape of a slot which can be covered by a flap comprising one or more apertures. The slot preferably extends parallel to the tube. The length of the aperture slots is suitably chosen according to the traverse length.

Nevertheless, the traversing device is preferably disposed within the housing, viewed in the direction of movement of the yarn advantageously before the tube onto which the multifilament yarn is wound. This makes it possible to minimize the size of the opening, so that the occurrence of a temperature gradient within the housing is ideally suppressed. In this case too, the opening preferably has the shape of a slot which can be covered by a flap comprising one or more apertures, the slot preferably extending parallel to the tube.

To remove the wound yarn package from the apparatus in accordance with the present invention, this apparatus can be opened in a suitable manner, in which case it is particularly advantageous for this opening to be provided in the form of a closable opening which can be closed during the spinning and winding in order that a constant temperature within the housing may be ensured. A particularly preferred embodiment of the closable opening is a door that can be opened to introduce the multifilament yarns or to remove the resulting wound yarn package and which can be closed during the spinning and winding. The closable opening is preferably disposed at the frontface of the housing. Briefly opening the door to remove the wound packages in the course of the automatic changing of the mandrel in the winding position has been determined to be uncritical.

Fig. 1 is a schematic representation of a particularly suitable embodiment of the apparatus. The apparatus 2 for winding comprises a housing 4. In the illustrated embodiment, the housing 4 takes the form of a housing having a lower wall 6, an upper wall 8, two side walls 10, 12, a front wall 14 and a back wall 16, the upper wall 8 facing in the direction of the oncoming multifilament yarns. The front wall 14 has the function of a door, ie the housing 4 can be opened or closed by

the front wall 14. At the back wall 16, a drive unit 18 is provided outside the housing 4.

The upper wall 8 has an opening 20 in the shape of a slot which extends from the front wall 14 in the direction of the back wall 16 and which extends parallel to the side walls 10, 12. The opening 20 is partly covered by a flap 22 which comprises apertures 24 through which the multifilament yarns 26 can pass into the housing 4 through the opening 20. Since the opening 20 extends right to the front wall 14, multifilament yarns 26 can be introduced from the side of the housing 4 when the front wall 14 and flap 22 are open.

Viewed in the direction movement of the multifilament yarn 26, the direction of movement being indicated by the arrow A in Fig. 1, a traversing unit 28 is disposed behind the opening 20, within the housing 4. The traversing unit 28 is connected to and driven by the drive unit 18 on the back wall 16. Viewed in the direction of movement A of the multifilament yarns 26, four tubes 30, for example, have been clamped onto the chuck of a rotatable spindle which is disposed behind the traversing unit 28, within the housing 4. The spindle is connected to the drive unit 18 such that the spindle and the tubes 30 which have been clamped onto the spindle can rotate along their axis during the operation of the drive unit 18.

Two temperature sensors 32 are disposed within the housing 4 for measuring the temperature within the housing and to control the heat flux, one of the sensors 32 being disposed behind the tube 30 and the other sensor before the tube 30, viewed in the direction of movement A of the multifilament yarns 26.

The housing 4 further comprises an outlet 34 which is disposed in the upper wall 8 and an inlet 36 which is

disposed in the back wall 16. In other words, viewed in the direction of movement A of the multifilament yarns 26, the outlet 34 is disposed before the tube 30 and the inlet 36 behind the tube 30. The outlet 34 can optionally be connected to a heating and blowing unit 38 through a circulation system 40, indicated by a broken line in Fig. 1, in order that the heated gas may be circulated and process costs be minimized. The inlet 36 is connected to the heating and blowing unit 38 through the circulation system 42. The heating and blowing unit 38 heats the gas, for example air, and blows the gas in the direction which is indicated by the arrow B in Fig. 1, so that the gas is circulated through the housing 4. The temperature in the region in which the tube is disposed can be controlled by controlling the setting parameters of the heating and blowing unit 38 with reference to the values which are measured by the sensors 32.

The operation of the above-described apparatus 2 will now be described. First, the multifilament yarns 26 have to be fixed, preferably by means of a pneumatic yarn-aspirating gun, on the tubes which are clamped on the chuck 30. For this reason, the front wall 14 and the flap 22 have to be opened, so that the multifilament yarn 26 can be introduced into the slotlike opening 20. After the multifilament yarns 26 have been introduced the opening 20 and the piecing operation to be executed by the winder control system has commenced, the front wall 14 and the flap 22 can be closed again, so that each multifilament yarn passes through its own aperture 24 in the flap. The yarns running onto the tubes 30 are traversed to build the wound yarn packages 44. During the winding of the multifilament yarns 26, a heated gas is passed into the housing 4 through the inlet 36 to heat the housing and the wound yarn packages 44 on the tubes 30. The heated gas is fed via the outlet 34 to the heating and blowing inlet 38 to thereby achieve a preselected temperature

for the wound yarn packages 44 and the multifilaments 26.

The process of the present invention makes it possible to produce wound yarn packages 44 on the tubes 30 that have a cheeselike shape, as diagrammatically represented in Fig. 2. Shrinking and deformation of the wound yarn packages 44 during storage or a compaction such that the wound yarn package can no longer be removed from the chuck or the formation of a saddle 50 having hard edges 52, as schematically represented in Fig. 3, is no longer observed. Unwinding problems during the further processing of the wound yarn packages therefore do not arise. The wound polyester yarn packages obtainable by the present process exhibit improved long-term stability in storage and are insensitive to elevated temperatures during storage and transportation. More particularly, they retain their advantageous properties and their cheeselike shape even in the course of storage for a prolonged period, such as 4 weeks for example.

The polyester multifilament yarn obtainable according to the present invention has after 4 weeks of storage under standard conditions

a) a breaking extension between >60% and 165%, preferably between 75 and 145%,
b) a boiloff shrinkage of 0 to 10%,
c) a normal Uster below 1.1%, preferably ≤ 0.9%,
d) a breaking load coefficient of variation ≤ 4.5%, and
e) a breaking extension coefficient of variation ≤ 4.5%.

The term standard conditions is known to one skilled in the art and defined via the German standard DIN 53802. Under standard conditions as per DIN 53802, the temperature is 20 ± 2°C and relative humidity 65 ± 2%.

It is additionally particularly advantageous for the purposes of the present invention for the boiloff shrinkage to be between 0 to 10% when measured directly after windup and to be less than 2% abs. lower after 4 weeks of storage under standard conditions. Transportation conditions up to 65°C may naturally cause the boiloff shrinkage to further decrease by at most 10% abs. It has been determined that, surprisingly, POY bobbins produced in this way have excellent further processing properties in that higher draw ratios can be employed compared with spinning without extensibility enhancer and the drawn or draw-textured yarn has high strength and uniform dyeability. The positive ratio of high extension and low boiloff shrinkage in POY is only obtainable by the inventive process of heat treatment for comparatively high residence times which are far above those of filament treatment methods involving for example godets or hotrails alone and at relatively low temperatures.

Methods for determining the indicated material parameters are very well known to those skilled in the art. They are discernible from the technical literature. Although most of the parameters can be determined in various ways, the following methods for determining the filament parameters will prove particularly advantageous for the purposes of the present invention:

The intrinsic viscosity is measured at 25°C in an Ubbelohde capillary viscometer and calculated by the familiar formula. The solvent used is a 3:2 w/w mixture of phenol and 1,2-dichlorobenzene. The concentration of the solution is 0.5 g of polyester per 100 ml of solution.

The melting point, the crystallization temperature and the glass transition temperature are each determined using a DSC calorimeter from Mettler. The sample is

initially heated to 280°C to melt it and then quenched. The DSC measurement is done in the range from 20°C to 280°C at a heating rate of 10 K/min. The reported temperatures are determined by the processor.

Multifilament density is determined in a density gradient column at a temperature of 23±0.1°C. The reagent used is n-heptane (C_7H_{16}) and tetrachloromethane (CCl_4). The result of the density measurement can be used to calculate the crystallinity on the basis of the density of the amorphous polyester D_a and the density of the crystalline polyester D_k. The calculation is described in the literature and for PTMT for example the corresponding values are D_a = 1.295 g/cm^3 and D_k = 1.429 g/cm^3.

Linear density is determined in a known manner using a precision reel and weighing means. The pretension used is advantageously 0.05 cN/dtex for POY and 0.2 cN/dtex for DTY.

Breaking strength and breaking extension are determined on a Statimat apparatus under the following conditions: the clamped length is 200 mm for POY and 500 mm for DTY, the rate of extension is 2 000 mm/min for POY and 1 500 mm/min for DTY and the pretension is 0.05 cN/dtex for POY and 0.2 cN/dtex for DTY. The maximum breaking load values are divided by the linear density to determine the breaking strength, and breaking extension is determined at maximum load.

Boiloff shrinkage is determined by treating filament skeins in water at 95±1°C for 10±1 min in a tensionless state. The skeins are prepared by reeling at a pretension of 0.05 cN/dtex for POY and 0.2 cN/dtex for DTY; the length measurement of the skeins before and after the thermal treatment is carried out at 0.2 cN/dtex. The difference in length is used to calculate the boiloff shrinkage in a known manner.

The crimp parameters of the textured filaments are measured in accordance with DIN 53840 Part 1 using a Texturmat apparatus from Stein/Germany at a development temperature of 120°C.

The normal Uster values are determined using a 4-CX Uster tester and are reported as Uster % values. The testing speed is 100 m/min and the testing time 2.5 min.

The theoretically calculated maximum draw ratio (Examples 1-3) is obtained by virtue of the addition of the extensibility enhancer additive at higher spinning speeds than without additive, and this in economic terms constitutes a capacity benefit. The theoretically calculated maximum draw ratio is between 1.6 and 2.65 and preferably between 1.75 and 2.45.

The polyester multifilament yarn according to the present invention is simple to further process, especially draw texture. In the present invention, draw texturing is preferably effected at a texturing speed of at least 500 m/min and more preferably at a texturing speed of at least 700 m/min. The draw ratio is preferably at least 1.35:1 and more preferably at least 1.40:1. It will be particularly advantageous to draw texture on a high temperature heater type machine, for example an AFK machine from Barmag.

The bulky filaments produced in this way exhibit a low number of defects and on dyeing at the boil with a disperse dye without carrier an excellent depth of shade and uniformity of color.

Bulky SET filaments produced according to the present invention preferably have a breaking strength of more than 20 cN/tex and a breaking extension of more than 32%. In the case of bulky HE filaments, which are

obtainable without thermal treatment in a second heater, the breaking strength is preferably more than 20 cN/tex and the breaking extension more than 30%.

The bulk and elasticity behavior of the multifilaments according to the present invention is excellent.

Illustrative embodiments of the invention will now be more particularly described without the invention being limited to these examples.

Inventive Examples 1 to 3

Spinning and winding

PTMT chips having an intrinsic viscosity of 0.93 dl/g, a melt viscosity of 325 Pa s (measured at 2.4 Hz and 255°C), a melting point of 227°C, a crystallization temperature of 72°C and a glass transition temperature of 45°C were tumble dried at 130°C to a water content of 11 ppm.

The chips were melted in a 3E4 extruder from Barmag, so that the temperature of the melt was 255°C. This melt had added to it various amounts of Plexiglas 7N polymethyl methacrylate from Röhm GmbH/Germany as an extensibility enhancer which had beforehand been dried to a residual moisture content of less than 0.1%.

For this purpose, the additive polymer was melted in a melting extruder, fed using a gear wheel metering pump to the feed means and fed from there through an injection nozzle in the flow direction into the polyester component. The two melts were homogenized and finely dispersed in an SMX static mixer from Sulzer having 15 elements and an internal diameter of 15 mm.

The melt viscosity of the Plexiglas 7N was 810 Pa s (2.4 Hz, 255°C), as a result of which the ratio of additive and polyester melt viscosities was 2.5:1.

The transported amount of melt was 63 g/min coupled with a residence time of 6 min, and the amount metered from the spinning pump to the spinneret pack was adjusted so that the POY linear density was about 102 dtex. Various takeup speed settings were used. One element of an HD-CSE type static mixer from Fluitec having an internal diameter of 10 mm had been installed below the spinning pump, but above the point of entry into the spinneret pack. The secondary heating systems for the product line and the spin block, which contained the pump and the spinneret pack, had been set to 255°C. The spinneret pack contained 350-500 µm steel sand 30 mm in height and also a 20 µm nonwoven filter and a 40 µm woven filter as filter media. The melt was extruded through an 80 mm diameter spinneret plate containing 34 holes 0.25 mm in diameter and 1.0 mm in length. The die pressure was about 120-140 bar.

The quench delay zone was 100 mm in length, made up of 30 mm in heated walling and 70 mm in insulation and unheated frame. The molten filaments were subsequently quenched with air flowing horizontally against the spinline over a length of 1500 mm. The quenching air had a flow rate of 0.35 m/sec, a temperature of 18°C and a relative humidity of 80%. The filaments became solid at about 800 mm below the spinneret.

A yarn oiler positioned at a distance of 1 050 mm from the spinneret was used to apply spin finish to the ends before converging. The oiler had a TriboFil surface and an inlet opening 1 mm in diameter. The amount of spin finish applied was 0.40%, based on fiber weight.

The converged spinline was then fed to the winding machine. The distance between the oiler and the first takeoff godet was 3.2 m. The conditioning time was between 95 and 140 ms. A pair of godets was S-wrapped by the yarn. Situated between the godets was a Temco

entangling jet, which was operated using an air pressure of 1.5 bar. In line with the speed setting, the takeup speed of the Barmag SW6 winder was set in such a way that the takeup yarn tension was about 6 cN. The winder had been installed in a box into which air was passed from an air heater and by means of a blower and which was closed-loop controlled such that a temperature of 63°C ± 1.5°C came to be established in the interior of the box at about 20 cm from the rotating yarn package.

A significant increase in productivity was obtained for all amounts of additive added. The 10 kg bobbins produced were readily removable from the winding mandrel. The POY yarns obtained were notable for good time constancy of the yarn properties over a storage period of 4 weeks under standard conditions as defined in DIN 53802. The boiloff shrinkage directly after spinning and winding was found to be in the range from 5 to 8% and was less than 2% abs. higher than that of the stored bobbins. The texturability and the uniformity of dyeing achieved were found to be excellent. The maximum draw ratio to be used was surprisingly high for the POY speeds used. With regard to the maximum draw ratio (DR) which can subsequently be applied, we have followed the definition in EPS 0 080 274 page 6 line 51: DR = (1 + POY extension(%)/100). To simulate transportation, bobbins having these parameters were exposed to a temperature of 60°C in a heating chamber for 20 hours. Bobbin shape and also textile data changed only insignificantly.

Comparative Example 4

Inventive Example 1 was repeated with following differences: the additive metering system was uncoupled from the product line, so that no extensibility enhancer was added. Furthermore, the winder box was removed and a temperature of 34°C became established at

the same measuring point in the environment of the wound package at a room temperature of 24°C.

The absence of the extensibility enhancer led to a lower extension being obtained compared with Inventive Example 1 and hence a lower maximum DR. The capacity and hence the economics of the spinning position decreased accordingly. The inadequate heat treatment of the wound yarn leads to a boiloff shrinkage of about 53%, which decreases by 9% abs. to 44% after storage. A subsequent 60°C treatment as above reduces the boiloff shrinkage by about 40% abs.

The other parameters and characteristic data are summarized in Tables 1 to 4.

Table 1: Experimental parameters

Experimental parameter		**Inventive Example 1**	**Inventive Example 2**
Additive concentration	[%]	0.7	1.0
Takeoff speed	[m/min]	3520	4022
Takeup speed	[m/min]	3500	4000
Spinline extension ratio		182	181
Yarn tensions			
above godets[1]	[cN]	15.5	16
between godets[1] max	[cN]	13	12.5
above godets[2]	[cN/dtex]	0.15	0.16
between godets[2] max	[cN/dtex]	0.13	0.12
Windup yarn tension[1]	[cN]	5.9	6.4
Windup yarn tension[2]	[cN/dtex]	0.058	0.062
Winder box		yes	yes

[1]: absolute

[2]: based on linear density

Table 1: Experimental parameters (continued)

Experimental parameter		**Inventive Example 3**	**Comparative Example 4**
Additive concentration	[%]	0.5	0
Takeoff speed	[m/min]	4517	3520
Takeup speed	[m/min]	4455	3500
Spinline extension ratio		182	182
Yarn tensions			
above godets[1]	[cN]	19	15
between godets[1] max	[cN]	13	13
above godets[2]	[cN/dtex]	0.19	0.15
between godets[2] max	[cN/dtex]	0.13	0.13
Windup yarn tension[1]	[cN]	6.5	5.9
Windup yarn tension[2]	[cN/dtex]	0.064	0.058
Winder box		yes	no

[1]: absolute

[2]: based on linear density

Table 2: Material properties of partially oriented PTMT filaments[1]

Material properties		**Inventive Example 1**	**Inventive Example 2**
Linear density	[dtex]	102.5	103
Breaking strength	[cN/tex]	21.8	22.3
Breaking extension	[%]	115.4	98.2
Normal Uster	[%]	0.90	0.84
Boiloff shrinkage	[%]	4.1	4.9
Breaking load CV	[%]	2.5	3.1
Breaking extension CV	[%]	2.9	3.3
Max. DR calculated		2.15	1.98

CV: coefficient of variation

[1]: measured after 4 weeks of storage under standard conditions

Table 2: Material properties of partially oriented PTMT filaments[1]

Material properties		**Inventive Example 3**	**Comparative Example 4**
Linear density	[dtex]	102	102.5
Breaking strength	[cN/tex]	23.1	25.6
Breaking extension	[%]	79.1	79.1
Normal Uster	[%]	0.90	0.98
Boiloff shrinkage	[%]	6.4	44
Breaking load CV	[%]	2.5	3.4
Breaking extension CV	[%]	3.4	4.9
Max. DR calculated		1.79	1.79

CV: coefficient of variation

[1]: measured after 4 weeks of storage under standard conditions

Draw texturing

The PTMT filament bobbins of Inventive Examples 1 and 2 were stored for 4 weeks under standard conditions as defined in German standard DIN 53802 and then presented to a Barmag FK6-S-900 draw-texturing machine. The experimental parameters for draw texturing to produce SET filaments are summarized in Table 3 and the material properties of the resulting bulky SET filaments are summarized in Table 4.

Texturing defects were determined using Barmag's UNITENS system at the following limiting value settings: UP/LP = 3.0 cN, UM/LM = 6.0 cN.

Table 3: Experimental parameters of draw texturing

Experimental parameter		**Inventive Example 1**	**Inventive Example 2**
Speed	[m/min]	700	700
Draw ratio		1.60:1	1.44:1
D/Y ratio		2.1	2.1
Heater 1 temp.	[°C]	155	155
Heater 2 temp.	[°C]	160	160
Texturing defects	[n/10 km]	0	0
Yarn tension			
F^1, above assembly	[cN]	23	22
F^2, below assembly	[cN]	21	20
F^2-CV	[%]	1.2	1.4

F^2-CV: coefficient of variation of F^2

Table 4: Material properties of draw-textured filaments

Experimental parameter		**Inventive Example 1**	**Inventive Example 2**
Linear density	[dtex]	69	79
Breaking strength	[cN/tex]	25.3	23.8
Breaking extension	[%]	34.8	35.3
Inspection of dyeability		uniform	uniform